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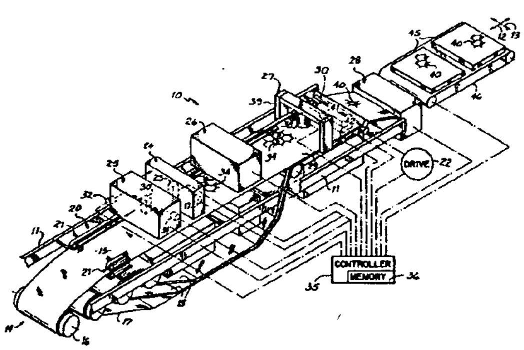
(54) Title: METHOD AND APPARATUS FOR UV INK JET PRINTING ON FABRIC AND COMBINATION PRINTING AND QUILTING THEREBY



(57) Abstract: A method and apparatus for inkjet printing is provided onto fabric (15) using ultraviolet (UV) light curable ink, the ink is first partially cured with UV light (24) and then is subjected to heating to more completely cure the ink. The printing is provided in a quilting machine (10) having a quilting station (27) and a printing station (25) located upstream of the quilting station. Preferably, at the printing station, only a top layer of fabric is printed with a multi-colored design under the control of a programmed controller (35). UV curable ink is jetteed onto the fabric with a dot volume of about 75 picoliters. A conveyor (20) moves the printed fabric from the printing station through a UV curing station (24) where a UV curing light head moves either with the print head or independent of the print head to expose the deposited drops of UV ink with a beam of about 300 watts per linear inch of energy, at a rate that applies about 1 joule per square centimeter. The conveyor then conveys the fabric through a heated drying station or oven (26) where the fabric is heated to about 300 degree F for about 30 seconds up to three minutes. Forced hot air is preferably used to apply the heat in the oven, but other heating methods such as infrared or other radiant heaters may be used. Before, or preferably after, the heat curing, the fabric is combined with other material layers and a quilted pattern is applied in program controlled coordination with the printed pattern.

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METHOD AND APPARATUS FOR UV INK JET PRINTING ON FABRIC AND COMBINATION PRINTING AND QUILTING THEREBY

The present invention relates to printing on fabric, and particularly to the printing of patterns onto fabric used in quilting such as onto multiple layer materials such as mattress covers, comforters, bedspreads and the like. The invention is more particularly related to the ink jet printing onto fabric, and to ink jet printing with ultra-violet light (UV) curable inks.

Background of the Invention

Quilting is a special art in the general field of sewing in which patterns are stitched through a plurality of layers of material over a two-dimensional area of the material. The multiple layers of material normally include at least three layers, one a woven primary or facing sheet that will have a decorative finished quality, one a usually woven backing sheet that may or may not be of a finished quality, and one or more internal layers of thick filler material, usually of randomly oriented fibers. The stitched patterns maintain the physical relationship of the layers of material to each other as well as provide ornamental qualities.

Frequently, a combining of stitched patterns with printed patterns is desirable, such as in mattress covers and other quilt manufacture. Producing a printed pattern on a mattress cover requires the application of ink to fabric, which, unlike paper, plastic or other smooth surfaces, presents a texture, third dimension or depth, to the surface on which the printing is applied. Furthermore, printing onto substrates that are more than several feet, or a meter, wide, referred to as the special category of "wide width" printing, into which category the printing of mattress ticking and most other quiltable materials would fall, is beyond many of the limitations of conventional printing methods. A number of technical problems exist that have deterred the development of the printing of wide fabrics such as mattress covers, upholstery, automobile seat cover fabrics, office partitions and other wide width fabrics.

Wide width products are frequently printed in relatively small quantities. Traditional printing typically involves the creation of a plate, a mat, a screen, or some other permanent or at least tangible, physical image from which ink is transferred to the object being printed. Such images contribute a relatively high set up cost that is only economical where the number of identical copies of the product is large. At the other extreme, office printers, for example, print a single copy or a small number of copies of a given document or other item, and are currently of the type that uses no permanent, physical image transfer element, but which rather prints from a software or program controlled electronic image, which can be changed from product to product. Such "soft" image printers are sometimes referred to as digital

printers, although the "soft" image need not necessarily be "digital" in the sense of a set of stored discrete numerical values. A common type of such "soft" image or digital printers in use today is the ink jet printer.

Ink jet printers print by projecting drops of ink on demand onto a substrate from one or more nozzles on one or more print heads. Office printers and other narrow width ink jet printers usually dispense water based or other solvent based inks onto the substrate by heating the ink and exploding bubbles of the ink out of the nozzles. These printers are commonly called bubble jet printers. The ink dries by evaporation of the solvent. Sometimes additional heat is used to evaporate the solvent and dry the ink. Printing onto wide width substrates with bubble type ink jet printers, or ink jet printers that use high temperature techniques to propel the ink, severely limits the life of the print head. The heat used to expel the ink and the evaporation of the solvents, particularly during downtime, and the thermal cycling of the heads, causes these print heads to clog or otherwise fail after as little as 20 milliliters of ink is dispensed. Office printers are, for example, often designed so that the print head is replaced every time a reservoir of ink is replenished. For this reason, for larger scale ink jet printing processes, such as wide width printing of films used for outdoor advertising, signage and architectural applications, print heads that use mechanical ink propulsion techniques are more common. Such mechanical print heads include piezo or piezo-crystal print heads, which convert electrical energy into intra-crystal vibrations that cause drops of ink to be ejected from print head nozzles.

Piezo print heads are particularly useful for applying inks that dry by polymerization which can be brought about after the ink leaves the print head and is deposited onto the substrate, usually by exposure to some form of energy medium such as electromagnetic or particle radiation. Inks have been formulated for ink jet printing that can be polymerized by exposure to a radiation curing source such as a focused beam of ultra violet light (UV) or high energy beams of electrons (EB). The inks generally incorporate stabilizers which prevent premature curing due to low levels of light exposure. Therefore, the inks usually require exposure to some threshold level of energy that is necessary to initiate a polymerization reaction. Unless exposed to such threshold energy levels, such inks do not polymerize and remain stable, with a low tendency to dry in the nozzles or elsewhere unless cured by adequate exposure to the energy medium.

Solvent based inks are primarily cured by evaporation of the solvents. Some solvent based inks cure only by air drying, while others require the application of heat to enhance the evaporation of the solvent. In some cases, heat will facilitate a chemical change or polymerization of the ink along with an evaporation of a solvent. Polymerizable inks include monomers and oligomers that polymerize, and other additives. UV curable inks polymerize when exposed to UV light at or above the threshold energy level. These UV curable ink formulations include photoinitiators which absorb light and thereby produce free radicals or cations which induce crosslinking between the unsaturation sites of the monomers, oligomers and polymers, as well as other additive components. Electron beam-cured inks do not require photoinhibitors because the electrons are able to directly initiate crosslinking.

Heat or air curable inks that are organic solvent based or water based inks often do not have as high a color intensity as UV curable or other polymerizable inks because the pigments or dyes that produce the color are somewhat diluted by the solvent. Furthermore, organic solvents can produce an occupational

hazard, requiring costly measures be taken to minimize contact of the evaporating solvents by workers and to minimize other risks such as the risks of fire. Solvent based inks. whether applied with heat or not, tend to dry out and eventually clog ink jet nozzles. In addition, solvent based inks set by forming a chemical bond with the substrate, and accordingly, their formulation is substrate material dependent. As a result, the selection of solvent based ink varies from fabric to fabric. Specific ink compositions are paired with specific fabric compositions to improve the fastness of the ink to the fabric, which results from chemical or electrostatic bonds formed between the ink and the fabric. With UV and other radiant beam-curable inks such as electron beam-cured inks, the bonding between the ink and fabric is primarily mechanical and not limited to specific combinations of ink and fabric.

Polymerizable inks, particularly those cured upon exposure to a radiation or energy medium, are difficult to cure on three dimensional substrates such as fabric. While UV curable inks are capable of providing higher color intensity and do not present the hazards that many solvent based inks present and can avoid nozzle clogging, printing with UV curable ink onto fabric presents other problems that have not been solved in the prior art. To cure UV ink, for example, it must be possible to precisely focus a UV curing light onto the ink. UV ink, when jetted onto fabric, particularly onto highly textured fabric, is distributed at various depths over the texture of the fabric surface. Furthermore, the ink tends to soak into or wick into the fabric. As a result, the ink is present at various depths on the fabric, so that some of the ink at depths above or below the focal plane of the UV curing light evade the light needed to cause a total cure of the ink. In order to cure, UV ink must be exposed to UV light at an energy level above a curing threshold. However, increasing the intensity of the curing light beyond certain levels in order to enhance cure of the ink can burn, scorch or otherwise have destructive effects on the deposited ink or the fabric. Furthermore, ink jet printing can be carried out with different ink color dots applied in a side-by-side pattern or in a dot-on-dot (or drop-on-drop) pattern, with the dot-on-dot method being capable of producing a higher color density, but the higher density dot-on-dot pattern is even more difficult to cure when the cure is by UV light.

In addition, UV ink can be applied quickly to reduce wicking and UV ink can be developed to allow minimized wicking. Some wicking, however, helps to remove artifacts. Further, inks developed to eliminate wicking leave a stiff paint-like layer on the surface of the fabric, giving the fabric a stiff feel or "bad hand". Therefore, to reduce the UV curing problem by eliminating wicking is not desirable.

UV curing of jetted ink on fabric has a limited cure depth that is determined by the depth of field of the focused curing UV light . When UV curable ink is jetted onto fabric, UV light may proceed to cure an insufficient portion of the ink. A large uncured portion of the deposited ink can cause movement or loss of the ink over time, resulting in deterioration of the printed images. Even if a sufficient portion of the ink is cured to avoid visibly detectable effects, uncured ink at some level has the possibility of producing symptoms in some persons who contact the printed fabric. The amount of uncured monomers or ink components that can cause problems by inhalation or direct skin contact has not been officially determined, but standards exist for determining limits for components of packaging material ingested with food. For example, if more than approximately 100 parts per million (PPM) of ink from packaging material is present in food, some persons who are sensitive to the uncured monomers may suffer reactions

and others may develop sensitivities to the material. Such criteria assumes that 1 square inch of packaging material makes contact with ten grams of food. Thus, to interpret this criteria, it is assumed that each PPM of ink component in packaged food is equivalent to 15.5 milligrams of ink component migrating out of each square meter of packaging material into the food. While this does not provide an exact measure of the amount of uncured ink components that might be harmful to humans, it suggests that approximately 10% of uncured ink components on items of clothing, mattress covers or other fabrics with which persons may be in contact for extended periods of time, may be unacceptable.

For the reasons stated above, UV curable inks have not been successfully used to print onto fabric where a high degree of cure is required. Heat curable or other solvent based inks that dry by evaporation can be cured on fabric. As a result, the ink jet printing of solvent based inks and heat curable or air dryable solvent based ink has been the primary process used to print on fabric. Accordingly, the advantages of UV or other radiation curable ink jet printing have not been available for printing onto fabric.

There exists a need in printing of patterns onto mattress ticking and mattress cover quilts, as well as onto other types of fabrics, for a process to bring about an effective cure of UV curable inks and to render practical the printing with UV curable inks onto fabric.

Summary of the Invention

An objective of the present invention is to provide an effective method and apparatus for wide width "digital" or "soft" image printing onto fabric. Another objective of the invention is to effectively apply and cure UV curable and other energy medium polymerizable ink onto fabric, and particularly using ink jet printing. A further objective of the invention is to successfully apply and effectively cure ink jetted onto fabric with a piezo or other mechanical or electro-mechanical print head.

A particular objective of the invention is to provide for the printing of UV ink or other inks that are curable by exposure to impinging energy, onto fabric, particularly highly textured fabrics such as, for example, quilts or mattress cover ticking. A particular objective of the invention is to provide for the effective curing of UV inks jetted onto fabric by reducing uncured monomers and other extractable non-solvent polymerization reactants, including reactant byproducts, or components of the ink, to a level most likely to be tolerable by or acceptable to persons contacting the printed substrates.

According to the principles of the present invention, ink is digitally printed onto fabric and polymerization of the ink is initiated by exposure to an impinged energy beam, such as UV, EB or other such energy beam, then the partially polymerized or cured ink is thereafter subjected to heat to reduce the unpolymerized polymerizable reactants and other extractable components of the ink to low levels that are likely to be tolerable or otherwise acceptable to persons contacting the fabric.

In certain embodiments of the invention, UV curable ink is jetted onto fabric and the cure of the ink is initiated by exposure to UV light. Preferably, a non-bubble jet print head such as a piezo-crystal or other mechanical ink ejection transducer is used to jet the ink. Heat may be applied to the piezo-crystal or other mechanical ink injection transducer during operation, but generally only for ink viscosity reduction. With or following the exposure to the UV light, the printed fabric is subjected to a heated air stream which either extends the UV light initiated curing process, drives off uncured components of the ink, or both. More particularly, UV curable ink is jetted onto a fabric, and the jetted ink is exposed to UV

curing light to cure the ink to an extent sufficient to stabilize the ink such that the printed image is substantially resistant to further wicking, which is generally about 60 to 95% polymerization depending on ink density, substrate porosity and composition, and substrate weight and thickness. Then, the fabric bearing the partially cured jetted ink is heated with heated air in a heat curing oven, at which the UV light initiated polymerization may continue, or uncured monomers are vaporized, or both, in order to produce a printed image of UV ink that contains a reduced level of uncured monomers or other components of the ink which is likely to be tolerable by persons sensitive or potentially sensitive to such ink components. Preferably, the uncured components of the ink are reduced to an order of magnitude of about a gram per square meter, for example, and generally not more than about 1.55 grams per square meter of uncured monomer on the fabric substrate.

According to the preferred embodiment of the invention, UV ink is jetted onto a highly textured fabric such as a mattress cover ticking material, preferably prior to the quilting of the fabric into a mattress cover. The ink is preferably jetted at a dot density of from about 180x254 dots per inch per color to about 300x300 dots per inch per color, though lower dot densities of from about 90x254 dots per inch can be applied. Preferably, four colors of a CMYK color palette are applied, each in drops or dots of about 75 picoliters, or approximately 80 nanograms, per drop, utilizing a UV ink jet print head. A UV curing light head is provided, which moves either with the print head or independent of the print head and exposes the deposited drops of UV ink with a beam of about 300 watts per linear inch, applying about 1 joule per square centimeter. Generally, UV ink will begin to cure, at least on the surface, at low levels of energy in the range of about 20 or 30 millijoules per square centimeter. However, to effect curing in commercial operation, higher UV intensities in the range of about 1 joule per square centimeter are desired. Provided that some minimal threshold level of energy density is achieved, which can vary based on the formulation of the ink, the energy of the beam can be varied as a function of fabric speed relative to the light head and the sensitivity of the fabric to damage from the energy of the beam. The fabric on which the jetted ink has been thereby partially UV cured is then passed through an oven where it is heated to about 300°F for from about 30 seconds up to about three minutes. Forced hot air is preferably used to apply the heat in the oven, but other heating methods such as infrared or other radiant heaters may be used. The UV energy level, oven heating temperature and oven heat time may be varied within a range of the above listed values depending on the nature of the fabric, the density and type of the applied ink and the speed of the fabric during processing relative to the UV curing light head. Thus, a higher ink density applied to the fabric will generally require more UV energy, higher oven heating temperature, longer oven heat time or a combination of these variables, to effect the necessary curing on the particular fabric. Generally, the upper limits for the UV or other impinging beam of energy and oven heating temperature are those values which, when applied to the specific ink and fabric, begin to damage or otherwise adversely affect the applied ink, the underlying fabric or both.

The invention has the advantage that, for different inks and using different criteria for the desired residual amount of uncured ink components remaining on the fabric, the parameters can be varied to increase or reduce the residual amount. By increasing or decreasing the intensity of energy, or using a different form of energy than UV, or by increasing or decreasing the time of exposure of the ink to the

energy, the amount of remaining unpolymerized non-solvent ink components can be changed. Additionally, using higher or lower temperatures, or more or less air flow, or greater or less heating time in the post curing oven, can change the final composition of the ink on the substrate. Care, however, should be taken that the energy curing or heating process does not damage the fabric or the ink.

The invention makes it possible to print images on fabric with UV curable ink by providing effective curing of the ink, leaving less than a nominal 1.55 grams of uncured monomers per square meter of printed material and usually leaving only about 0.155 grams per square meter of uncured monomers. Thus, the invention provides the benefits of using UV curable ink over water and solvent based inks, including the advantages of high color saturation potential, low potential sensitivity or toxicity, and without clogging the jet nozzles and enabling the use of piezo or other high longevity print heads. Furthermore, the ability to print on wide width fabrics with polymerizable inks, which do not form chemical bonds with the substrates, and therefore are not material dependent, provides an advantage, particularly with fabrics such as mattress covers and other furniture and bedding products.

These and other objects of the present invention will be more readily apparent from the following detailed description of the preferred embodiments of the invention.

Brief Description of the Drawing

The figure is a diagrammatic perspective view of a one embodiment of a web-fed mattress cover quilting machine embodying principles of the present invention.

Detailed Description of the Preferred Embodiment

The figure illustrates a quilting machine 10 having a stationary frame 11 with a longitudinal extent represented by an arrow 12 and a transverse extent represented by an arrow 13. The machine 10 has a front end 14 into which is advanced a web 15 of ticking or facing material from a supply roll 16 rotatably mounted to the frame 11. A roll of backing material 17 and one or more rolls of filler material 18 are also supplied in web form on rolls also rotatably mounted to the frame 11. The webs are directed around a plurality of rollers (not shown) onto a conveyor or conveyor system 20, each at various points along the conveyor 20. The conveyor system 20 preferably includes a pair of opposed pin tentering belt sets 21 which extend through the machine 10 and onto which the outer layer 15 is fed at the front end 14 of the machine 10. The belt sets 21 retain the web 15 in a precisely known longitudinal position thereon as the belt sets 21 carry the web 15 through the longitudinal extent of the machine 10, preferably with an accuracy of 0 to 1/4 inch. The longitudinal movement of the belts 21 is controlled by a conveyor drive 22. The conveyor 20 may take alternative forms including, but not limited to, opposed cog belt side securements, longitudinally moveable positive side clamps that engage and tension the material of the web 15 or other securing structure for holding the facing material web 15 fixed relative to the conveyor 20.

Along the conveyor 20 are provided three stations, including an ink jet printing station 25, a UV light curing station 24, a heated drying station 26, a quilting station 27 and a panel cutting station 28. The backing material 17 and filler material 18 are brought into contact with the top layer 15 between the drying station 26 and the quilting station 27 to form a multi-layered material 29 for quilting at the quilting station 27. Preferably, the layers 17,18 are not engaged by the belt sets 21 of the conveyor 20, but rather, are brought into contact with the bottom of the web 15 upstream of the quilting station 27 to extend

beneath the web 15 through the quilting station 27 and between a pair of pinch rollers 44 at the downstream end of the quilting station 27. The rollers 44 operate in synchronism with the belt sets 21 and pull the webs 17,18 through the machine 10 with the web 15.

The printing station 25 includes one or more ink jet printing heads 30 that are transversely moveable across the frame 11 and may also be longitudinally moveable on the frame 11 under the power of a transverse drive 31 and an optional longitudinal drive 32. Alternatively, the head 30 may extend across the width of the web 15 and be configured to print an entire transverse line of points simultaneously onto the web 15.

The ink jet printing head 30 is configured to jet UV ink at 75 picoliters, or approximately 80 nanograms, per drop, and to do so for each of four colors according to a CMYK color pallette. Preferably, the printing head 30 does not undergo a heating step during operation. A mechanical or electro-mechanical print head such as a piezo print head is preferred. The dots are preferably dispensed at a resolution of about 180 dots per inch by about 254 dots per inch. The resolution may be higher or lower as desired, but the 180x254 resolution is preferred. If desirable for finer images or greater color saturation, 300x300 dots per inch is preferable. The drops of the different colors can be side-by-side or dot-on-dot. Dot-on-dot (sometimes referred to as drop-on-drop) produces higher density.

The print head 30 is provided with controls that allow for the selective operation of the head 30 to selectively print two-dimensional designs 34 of one or more colors onto the top layer web 15. The drive 22 for the conveyor 20, the drives 31,32 for the print head 30 and the operation of the print head 30 are program controlled to print patterns at known locations on the web 15 by a controller 35, which includes a memory 36 for storing programmed patterns, machine control programs and real time data regarding the nature and longitudinal and transverse location of printed designs on the web 15 and the relative longitudinal position of the web 15 in the machine 10.

The UV curing station 24 includes a UV light curing head 23 that may move with the print head 30 or, as is illustrated, move independently of the print head 30. The UV light curing head 23 is configured to sharply focus a narrow longitudinally extending beam of UV light onto the printed surface of the fabric. The head 23 is provided with a transverse drive 19 which is controlled to transversely scan the printed surface of the fabric to move the light beam across the fabric. Preferably, the head 23 is intelligently controlled by the controller 35 to selectively operate and quickly move across areas having no printing and to scan only the printed images with UV light at a rate sufficiently slow to UV cure the ink, thereby avoiding wasting time and UV energy scanning unprinted areas. If the head 23 is included in the printing station 25 and is coupled to move with the print head 30, UV curing light can be used in synchronism with the dispensing of the ink immediately following the dispensing of the ink.

The UV curing station 24, in the illustrated embodiment, is located immediately downstream of the printing station 25 so that the fabric, immediately following printing, is subjected to a UV light cure. In theory, one photon of UV light is required to cure one free radical of ink monomer so as to set the ink. In practice, one joule of UV light energy is supplied by the UV curing head 23 per square centimeter of printed surface area. This is achieved by sweeping a UV beam across the printed area of the fabric at a power of 300 watts per linear inch of beam width and exposing the surface for a time sufficient to deliver

the energy at the desired density. Alternatively, if fabric thickness and opacity are not too high, curing light can be projected from both sides of the fabric to enhance the curing of the UV ink. Using power much higher can result in the burning or even combustion of the fabric, so UV power has an upper practical limit.

The heat curing or drying station 26 is fixed to the frame 11, preferably immediately downstream of the UV light curing station. With sufficient UV cure to stabilize the ink such that the printed image is substantially resistant to further wicking, the ink will be sufficiently color-fast so as to permit the drying station to be off-line, or downstream of the quilting station 27. When on-line, the drying station should extend sufficiently along the length of fabric to adequately cure the printed ink at the rate that the fabric is printed. Heat cure at the oven or drying station 26 maintains the temperature of the ink on the fabric at about 300°F for up to three minutes. Heating of from 30 seconds to 3 minutes is the anticipated acceptable range. Heating by forced hot air is preferred, although other heat sources, such as infrared heaters, can be used as long as they adequately penetrate the fabric to the depth of the ink.

The exact percentage of tolerable uncured monomers varies from ink to ink and product to product. Generally, it is thought that uncured monomers of UV curable ink should be reduced to below about 0.1%, or 1000 PPM. In the preferred embodiment of the invention, uncured monomers of UV curable ink are reduced to less than 100 PPM, and preferably to about 10 PPM. As explained above, each 1 PPM is equivalent to about 15.5 milligrams extractables per square meter of printed material. As used herein, the percentage or portion of remaining uncured monomers refers to the mass of extractable material that can be removed from a given sample of cured ink by immersing the cured ink sample in an aggressive solvent such as toluene, and measuring the amount of material in the solvent that is removed from the ink by the solvent. The measurements are made with a gas chromatograph with a mass detector. In the preferred embodiment of the invention, the measured amount of material removed from a given sample of the ink is less than 1.5 grams extractables per square meter of printed material. Measurements of higher than 100 PPM or 1.5 grams extractables per square meter of printed material are undesirable. Measurements of 10 PPM are preferred.

Table 1 below sets out the extraction data generated on a single fabric printed with different patterns. The individual fabric samples for each run are cut from the same relative location on the web and contain the same printed pattern. The fabric sample containing the printed ink is immersed in a container having a fixed quantity of toluene and stored under ambient conditions for several days to extract any non-polymerized ink component. The fabric is a 51% polyester/49% cotton blend. The first pattern is a flower pattern with imprinted fabric sections; the second is a full color print consisting of four color CMYK with 100% jetting of each color dot-on-dot over the entire available fabric surface.

TABLE 1

Flower Pattern Fabric: UV/Heat Cure Process/Fabric Speed	Toluene Extractables (milligrams/square meter)
400 watts/no heat/20" per minute	3971
600 watts/no heat/20" per minute	1910
600 watts/no heat/6" per minute	637
600 watts/300F for 3 minutes/20" per minute	127
600 watts/300F for 3 minutes/6" per minute	25
Full Color Fabric:	
600 watts/no heat/6" per minute	8274
600 watts/300F for 3 minutes/20" per minute	509
600 watts/300F for 3 minutes/6" per minute	140

The quilting station 27 is located downstream of the oven 26 in the preferred embodiment. Preferably, a single needle quilting station such as is described in U.S. Patent Application Serial No. 08/831,060 to Jeff Kaetterhenry, et al. and entitled Web-fed Chain-stitch Single-needle Mattress Cover Quilter with Needle Deflection Compensation, which is expressly incorporated by reference herein, now U.S. Patent No. 5,832,849. Other suitable single needle type quilting machines with which the present invention may be used are disclosed in U.S. Patent Applications Serial Nos. 08/497,727 and 08/687,225, both entitled Quilting Method and Apparatus, expressly incorporated by reference herein, now U.S. Patents Nos. 5,640,916 and 5,685,250, respectively. The quilting station 27 may also include a multi-needle quilting structure such as that disclosed in U.S. Patent No. 5,154,130, also expressly incorporated by reference herein. In the figure, a single needle quilting head 38 is illustrated which is transversely moveable on a carriage 39 which is longitudinally moveable on the frame 11 so that the head 38 can stitch 360° patterns on the multi-layered material 29.

The controller 35 controls the relative position of the head 38 relative to the multi-layered material 29, which is maintained at a precisely known position by the operation of the drive 22 and conveyor 20 by the controller 35 and through the storage of positioning information in the memory 36 of the controller 35. In the quilting station 27, the quilting head 38 quilts a stitched pattern in registration with the printed pattern 34 to produce a combined or composite printed and quilted pattern 40 on the multi-layered web 29. This may be achieved, as in the illustrated embodiment by holding the assembled web 29 stationary in the quilting station 27 while the head 38 moves, on the frame 11, both transversely under the power of a transverse linear servo drive 41, and longitudinally under the power of a longitudinal servo drive 42, to stitch the 360° pattern by driving the servos 41,42 in relation to the known position of the pattern 34 by the controller 35 based on information in its memory 36. Alternatively, the needles of a single or multi-needle quilting head may be moved relative to the web 29 by moving the quilting head 38 only transversely relative to the frame 11 while moving the web 29 longitudinally relative to the quilting

station 27, under the power of conveyor drive 22, which can be made to reversibly operate the conveyor 20 under the control of the controller 35.

In certain applications, the order of the printing and quilting stations 25,27, respectively, can be reversed, with the printing station 25 located downstream of the quilting station 27, for example the station 50 as illustrated by phantom lines in the figure. When at the station 50, the printing is registered with the quilting previously applied at the quilting station 27. In such an arrangement, the function of the curing station 26 would also be relocated to a point downstream of both the quilting station 27 and printing station 50 or be included in the printing station 50, as illustrated.

The cutoff station 28 is located downstream of the downstream end of the conveyor 20. The cutoff station 28 is also controlled by the controller 35 in synchronism with the quilting station 27 and the conveyor 20, and it may be controlled in a manner that will compensate for shrinkage of the multi-layered material web 29 during quilting at the quilting station 27, or in such other manner as described and illustrated in U.S. Patent No. 5,544,599 entitled Program Controlled Quilter and Panel Cutter System with Automatic Shrinkage Compensation, hereby expressly incorporated by reference herein. Information regarding the shrinkage of the fabric during quilting, which is due to the gathering of material that results when thick, filled multi-layer material is quilted, can be taken into account by the controller 35 when quilting in registration with the printed pattern 34. The panel cutter 28 separates individual printed and quilted panels 45 from the web 38, each bearing a composite printed and quilted pattern 40. The cut panels 45 are removed from the output end of the machine by an outfeed conveyor 46, which also operates under the control of the controller 35.

Piezo print heads useful for this process are made by Spectra of New Hampshire. UV curing heads useful for this process are made by Fusion UV Systems, Inc., Gaithersburg, Maryland.

The above description is representative of certain preferred embodiments of the invention. Those skilled in the art will appreciate that various changes and additions which may be made to the embodiments described above without departing from the principles of the present invention.

Therefore, the following is claimed:

1. A quilting method comprising the steps of:

jetting UV curable ink onto a fabric to form a printed pattern on the fabric;

curing the ink on the fabric;

combining one or more secondary layers of material with the fabric; and

quilting a quilted pattern on the combined layers of material and fabric over the pattern printed on the fabric.

2. The method of claim 1 wherein the curing step includes the steps of:

exposing the UV curable ink jetted onto the fabric to UV light to at least partially cure the ink on the fabric; and

heating the fabric having the at least partially cured UV light cured ink thereon to reduce uncured UV curable ink.

3. The method of claim 2 further comprising heating the fabric having the at least partially cured UV light cured ink thereon to reduce uncured UV curable ink to 100 PPM or less.

4. The method of claim 1 wherein the curing step includes the steps of:

exposing the UV curable ink jetted onto the fabric with a beam of about 300 watts per linear inch of UV light at a rate sufficient to apply about 1 joule per square centimeter of the ink; and

heating the fabric having the at least partially cured UV light cured ink thereon to reduce uncured UV curable ink.

5. The method of claim 1 wherein the curing step includes the steps of:

exposing the UV curable ink jetted onto the fabric to UV light to at least partially cure the ink on the fabric; and

heating the fabric having the at least partially cured UV light cured ink thereon to about 300°F for at least about 30 seconds to reduce uncured UV curable ink.

6. The method of claim 1 wherein the curing step includes the steps of:

exposing the UV curable ink jetted onto the fabric with a beam of about 300 watts per linear inch of UV light at a rate sufficient to apply about 1 joule per square centimeter of the ink; and

heating the fabric having the at least partially cured UV light cured ink thereon to about 300°F for at least about 30 seconds to reduce uncured UV curable ink to less than 100 PPM.

7. A method of printing on fabric comprising the steps of:

jetting UV curable ink onto a fabric to form a printed pattern on the fabric; then

substantially curing the jetted ink on the fabric by exposing the UV curable ink to UV light, the curing resulting in substantially cured UV ink on the fabric containing more than an acceptable level of uncured monomers of the UV curable ink; then

heating the fabric having the substantially cured UV light cured ink thereon and thereby reducing the level of the uncured monomers of the UV curable ink on the fabric to an acceptable level.

8. The method of claim 7 wherein the heating step includes the step of:

heating the fabric having the substantially cured UV light cured ink thereon and thereby reducing uncured monomers of the UV curable ink on the fabric to 100 PPM or less.

9. The method of claim 7 wherein the heating step includes the step of:

heating the fabric having the substantially cured UV light cured ink thereon and thereby reducing uncured monomers of the UV curable ink on the fabric to less than 100 PPM.

10. The method of claim 7 wherein the ink jetting step includes the step of

jetting the UV curable ink at a dot density of at least about 180 dots per inch, each dot including about 75 picoliters of the ink.

11. The method of claim 7 wherein the curing step includes the step of:

exposing the UV curable ink jetted onto the fabric with a beam of about 300 watts per linear inch of UV light for a time that is sufficient to apply about 1 joule per square centimeter of the ink.

12. The method of claim 7 wherein the heating step includes the step of:

heating the fabric having the substantially cured UV light cured ink thereon to about 300°F for at least about 30 seconds.

13. A fabric printing apparatus comprising:

a supply of UV curable ink;

an ink jet print head positioned to deposited a dot pattern of UV curable ink onto a fabric;

a UV light curing head positioned relative to the ink jet print head and configured to expose the dot pattern deposited by the ink jet print head on the fabric to UV light of sufficient energy to substantially, but not completely, cure the ink;

a heat curing station positioned relative to the UV light curing head to heat the fabric having the exposed dot pattern thereon with energy sufficient to substantially reduce the fraction of uncured monomers of the UV curable ink on the fabric; and

means for conveying the fabric sequentially past the print head, then the curing head, then the heat curing station.

14. The apparatus of claim **13** wherein:

the UV light curing head is operative to expose the pattern to UV light at an intensity sufficient to cure the UV curable ink deposited on the fabric to at least 60% cure; and

the heat curing station is operative to heat the exposed pattern to a temperature and for a time sufficient to reduce the portion of uncured UV curable ink on the fabric.

15. The apparatus of claim **13** wherein:

the UV light curing head is operative to expose the pattern to UV light at an intensity sufficient to cure the UV curable ink deposited on the fabric to at least 60% cure.

16. The apparatus of claim **13** wherein:

the heat curing station is operative to heat the exposed pattern to a temperature and for a time sufficient to reduce the portion of uncured UV curable ink on the fabric.

17. A quilting apparatus comprising the printing apparatus of claim **13** and further comprising:

a quilting station positioned to quilt a quilted pattern onto the fabric.

18. The apparatus of claim 13 wherein the ink jet print head is configured to dispense the UV curable ink onto the fabric at a dot density of at least about 180 dots per inch, each dot including about 75 picoliters of the ink.

19. The apparatus of claim 13 wherein the UV light curing head is configured to expose the UV curable ink on the fabric to a beam of about 300 watts per linear inch of UV light for a time sufficient to apply about 1 joule of UV light energy per square centimeter of the ink.

20. The apparatus of claim 13 wherein the heat curing station is configured to heat the at least partially cured UV light cured ink on the fabric to about 300°F for at least about 30 seconds.

21. A method of printing onto a substrate comprising the steps of:

depositing polymerizable ink onto the substrate;

polymerizing the ink by initiating a polymerizing reaction in the ink and maintaining the reaction until the ink is substantially polymerized but contains at least some volatile unpolymerized monomers; then

drying the substantially polymerized ink to reduce content of volatile unpolymerized monomers in the ink deposited on the substrate.

22. The method of claim **21** wherein:

the depositing of the ink includes jetting ink onto the substrate to form a printed pattern on the substrate.

23. The method of claim **21** wherein:

the depositing of the ink includes depositing UV curable ink onto the substrate; and

the polymerizing of the ink on the substrate includes exposing the UV curable ink to UV light.

24. The method of claim **21** wherein:

the drying of the ink includes heating the substantially polymerized ink on the substrate and thereby reducing volatile ink components on the substrate to tolerable levels.

25. The method of claim **24** wherein;

the drying includes flowing hot air onto the substrate having the substantially polymerized UV curable ink thereon.

26. The method of claim **21** wherein:

the depositing of the ink includes jetting UV curable ink onto the substrate to form a printed pattern on the substrate;

the polymerizing of the jetted ink on the substrate includes exposing the UV curable ink on the substrate to UV light;

the drying of the ink includes heating the substantially polymerized UV light curable ink on the substrate and thereby reducing volatile UV curable ink components on the substrate to tolerable levels.

27. The method of claim **26** wherein;

the drying includes flowing hot air onto the substrate having the substantially polymerized UV curable ink thereon.

28. The method of claim **26** wherein;

the drying includes flowing hot air onto the substrate having the substantially polymerized UV curable ink thereon to evaporate at least some of the unpolymerized monomers of ink from the substrate.

29. The method of claim **26** wherein;

the drying includes flowing hot air onto the substrate having the substantially polymerized UV curable ink thereon to further polymerize at least some of the unpolymerized monomers of ink from the substrate.

30. A method of printing onto a substrate comprising the steps of:

digitally depositing polymerizable ink onto the wide width substrate;

impinging a beam of energy onto the deposited ink and thereby maintaining a polymerizing reaction in the ink until the ink is substantially polymerized but contains at least some extractable unpolymerized polymerization reactants; then

heating the substantially polymerized ink to reduce the content of unpolymerized reactants in the ink deposited on the substrate.

31. The method of claim **30** wherein;

the drying includes flowing hot air onto the substrate having the substantially polymerized curable ink thereon.

32. The method of claim **30** wherein;

the depositing of the ink is by jetting the ink from at least one print head.

33. The method of claim **30** wherein;

the depositing of the ink is by jetting the ink at low temperature from at least one print head.

34. The method of claim **30** wherein;

the depositing of the ink is by jetting the ink from at least one print head by essentially mechanical action of a print head element.

35. The method of claim **30** wherein;

the depositing of the ink is by jetting the ink from at least one piezo-electric print head.

36. The method of claim **30** wherein;

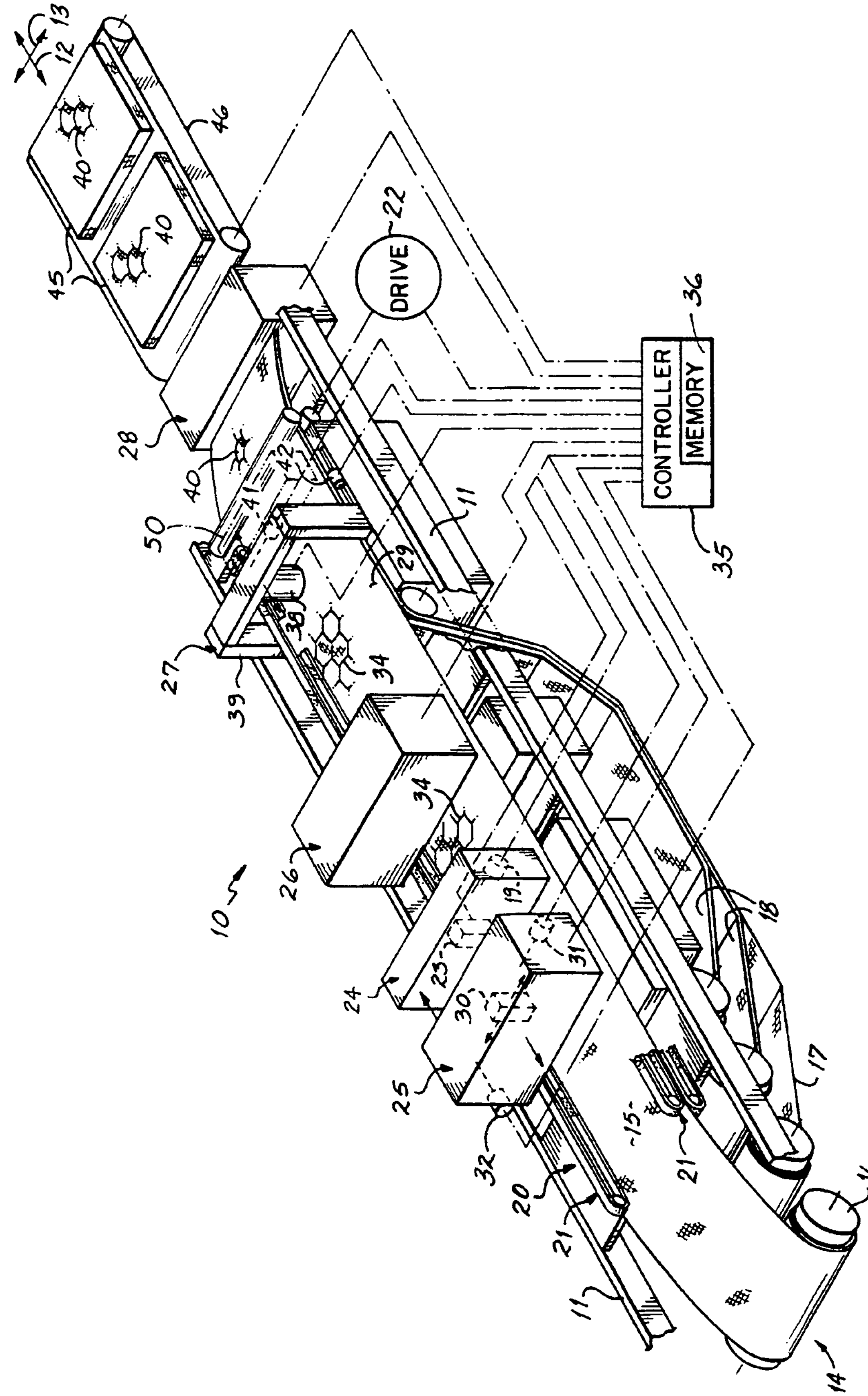
the depositing of the ink includes depositing UV curable ink and the impinging of the energy beam includes focusing a beam of ultraviolet light onto the deposited ink.

37. The method of claim **30** wherein;

the depositing of the ink includes depositing EB curable ink and the impinging of the energy beam includes focusing a beam of electrons onto the deposited ink.

38. The method of claim **30** wherein;

the depositing of the ink includes depositing polymerizable ink containing no substantial amount of solvent.


DRIVE
CONTROLLER
MEMORY

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/24226

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : B41J 2/01
US CL : 347/102

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 347/101, 347/102, 399/251, 399/341, 399/296, 112/117

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WEST
Search Terms: quilting and UV curable ink, curing ink and fabric

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y/A	US 5,873,315 A (Codos) 23 February 1999 (23.02.1999) column 2, lines 33-52; figure 1, element 27	1-2, 7, 10 & 13-18/19, 20
Y	GB 2,322,597 A (Roth et al.) 02 September 1998 (02.09.1998) page 8, line 28; figure 1, element 51,56;	1-2, 7 & 10
Y	US 5,396,275 A (Koike et al.) 07 March 1995 (07.03.1995) column 4, line 62-68	10 & 18
Y, P	US 6,092,890 A (Wen et al.) 25 July 2000 (25.07.2000) figure 1, element 40-43; figure 1, element 31-34; figure 1, element 50; figure 2	13-18 & 32-38
Y	US 4,197,563 A (Michaud) 08 April 1980 (08.04.1980) figure 1, element 1,2,10	21-31
Y	US 5,774,155 A (Medin et al.) 30 June 1998 (30.06.1998) figure 1, element 72,90	21-31

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report 03 NOV 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer John E. Barlow, Jr. Telephone No. 305-4900

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Continuation of B. FIELDS SEARCHED Item3: